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955 L'ENFANT PLAZA NORTH, S.W.   WASHINGTON, D. C. 20024

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SUBJECT: SL-2, 3, and 4 Launch and Recovery
Opportunity Lighting Variations for
November 9 SL-1 Launch - Case 610

DATE: December 17, 1970

FROM: D. A. Corey
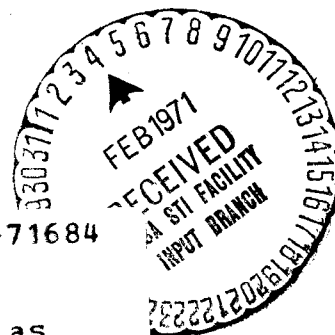E. W. Radany

ABSTRACT

A graphical device which displays the effects of
SL-1 launch time and the interval between launches on the
launch and recovery opportunity lighting conditions for the
later missions is presented. The use of the device is
demonstrated by means of examples.

Factors other than launch and recovery lighting
which must be considered in contriving the most favorable
combination of SL-1 launch time and the mission sequence
are discussed. These include the variation of beta as it
affects guidance requirements, and the desirable character-
istics of EREP photography opportunity distributions.

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MEMORANDUM FOR FILE

1.0 Introduction

     November 9 was recently designated as the launch
date for SL-1; it is planned that SL-2 will be launched one
or two days later. The launch time selected for SL-1, in
concert with the number of days between launches and the
durations of the missions, will uniquely determine the lighting
conditions prevalent during launch and recovery opportunities.
This is because the launch and recovery sites each rotate into
the workshop orbit plane 0.4 hours earlier each successive day
due to the combined effects of orbital regression and the
earth's rotation. This memorandum presents a device which
graphically displays these interrelations.

2.0 Device Description

     A graphical device for determining the relationships
between launch conditions and the subsequent lighting at
various specific latitudes was presented previously; Refer-
ence 1. The device presented here is quite similar in nature.
However, instead of presenting the lighting conditions at
various latitudes selected from the standpoint of performing
photography, lighting data specifically for the launch and
recovery site latitudes (viz. launch -28.65°N, Pacific recovery -
21.4°N, Atlantic recovery - 32°N) are presented. For the
present purpose, "daylight" is interpreted to mean the interval
from two hours before sunrise until two hours before sunset.
Due to the long duration (236 days) of the total Skylab program,
the seasonal variations of sunrise and sunset were factored
into the preparation of the data.

     The lighting data for the three latitudes of
interest are keyed together in order to display as a unit
the lighting prevailing at launch, and the corresponding
lighting at the two recovery sites at the end of the mission.
A block of such three-latitude data is presented as a trans-
parency for each of the SL-2, SL-3, and SL-4 missions;
Figure 1. An additional figure bearing scales of "SL-1

launch time" and "date of launch relative to nominal" is
also provided as a base on which the three mission trans-
parencies can be manipulated; Figure 2. The last component
of this mission planning device is a transparency carrying
a single vertical line; Figure 3. This is employed in the
same manner as the cursor of a slide rule.

The clock times indicated on the transparencies
are in terms of Eastern Standard Time for the launch scales
and Local Mean Solar Time for the recovery scales. The
scale marked "Atlantic Rec." presents time and lighting
information for the descending crossing of 32°N latitude
and, strictly speaking, is valid regardless of whether or
not the earth is oriented such that the Atlantic Ocean is
under that part of the orbit. That is, the data is equally
valid for a descending crossing recovery at 32°N in the
Pacific. Similarly, the scale marked "Pacific Rec."
presents time and lighting information for an ascending
crossing of 21.4°N latitude. The designations "Atlantic"
and "Pacific" are used simply because an ascending recovery
in the Pacific and a descending recovery to the Atlantic
offer post retro-burn ground tracking.

The concepts to keep in mind when using the device
are that given the time of day of launch, and the nominal
insertion conditions, the orientation of the orbit with
respect to the sun is predictable with substantial accuracy
for the Skylab mission duration. The location of the space-
craft in its orbit, however, is essentially totally unpre-
dictable for Skylab mission durations. Once the central
meridian for the landing recovery zone is selected, it is
only possible to predict pre-mission, the time of landing
expressed in say, Eastern Standard Time, to within + about
45 minutes. The local time at the recovery site is accurately
predictable and of course, this is the parameter of interest
since it indicates the amount of daylight remaining for the
recovery operations.

It should further be noted that the times shown
on the scales are correct regardless of SL-1 launch date
though the exact time of sunrise and sunset would be some-
what erroneous.

After removing the two transparencies and the
base figure from the memorandum, the simplest version of
the device can be assembled as follows. Separate the
lighting data into three strips by cutting on the lines
indicated. Position the three strips in horizontal rows

on the base figure, parallel to the two scales at the bottom.
Next, lay the cursor transparency on top with the cursor line
running vertically. The strips for the three missions can
now be individually slid to the right or left, as can the
cursor line.

Positioning the three mission strips so that the
vertical "nominal" marks all line up with "0" on the "date
of launch relative to nominal" scale sets up the conditions
for the nominal mission sequence; i.e., SL-2 launched on
day 1 and recovered on day 29, SL-3 launched on day 90 and
recovered on day 146, and SL-4 launched on day 180 and
recovered on day 236. Setting the cursor on a selected SL-1
launch time using the appropriate scale at the bottom of
the base figure displays the resulting lighting conditions
and local times of occurrences for the launch and recovery
events of the nominal mission sequence. For example, a noon
launch of SL-1 would have the following impact on the nominal
mission sequence. SL-2 would have to be launched at about
11:30. Twenty-eight days later, SL-2 could be recovered
either at night in the Pacific at about a half an hour before
midnight, or in the Atlantic at about 08:30. SL-3 would
then nominally be launched just after midnight, and fifty-six
days later could be recovered in the Pacific, again at night,
at about one o'clock in the morning. SL-4 could be launched
in daylight a few minutes after noon, and could be recovered
in the Pacific a few minutes before 13:00, fifty-six days
later.

The effect of advancing or delaying the launch of
a particular mission is revealed by sliding the data block
for the mission to the right or left by the appropriate
number of days on the "date of launch relative to nominal"
scale. Consider two examples of SL-1 again launched at noon.
First, SL-3 is to be launched ten days early (i.e., on day
80), and second, SL-4 is to be launched ten days late (i.e.,
on day 190). With these mission modifications the launch of
SL-3 would be at night (about 04:00), while the launch of
SL-4 would be in the morning (about 08:15). A daylight
Pacific recovery of SL-3 shortly before 05:00 and a daylight
Pacific recovery of SL-4 at about 09:00 could then be
scheduled after missions of the nominal 56-day mission.

The recovery zone lighting which will be available
in the event of an early manned mission termination can also
be determined since it is equivalent to the nominal return
conditions for a launch the same number of days earlier.

Since it may be desirable to consider other possible recovery points (that is - other latitudes), Figure 4 presents the differences in local time at the orbit crossings relative to the times shown in Figure 1 as a function of latitude. The difference obtained from the curve labeled "Ascending" should be applied to the data for the Pacific recovery. The "Descending" differences are to be applied to the Atlantic recovery times. If desired, it is a simple matter to construct transparencies similar to those in Figure 1 for other recovery latitudes. Simply shift the recovery scale hour marks on Figure 1 by the amounts indicated by Figure 4. Local time of sunrise and sunset data for the latitude of interest can be added by consulting, for example, the daily pages of the Nautical Almanac.

It is apparent from the preceding examples that the four degrees of freedom inherent in this mission planning device permit the rapid visualization of the effects on launch and recovery lighting of all possible launch time/mission sequence combinations. The question of the most favorable SL-1 launch time/mission sequence combination is addressed in the following section.

3.0 Discussion

A few simple manipulations with this device will disclose the SL-1 launch time/mission sequence combinations which permit daylight launches and recoveries, and/or allow some number of days of early daylight recovery, and/or allow some minimum number of days of daylight launch capability, etc., can be quite easily contrived. It is therefore, apparent that the most favorable "answer" cannot be obtained solely on the basis of launch and recovery lighting considerations. Paramount among the other factors which must necessarily be taken into account are pad turn-around times, the time history of the angle of the solar vector to the orbit plane (beta), the distributions of Earth Resources Experiment Package (EREP) photography opportunities, and the distributions of cloud cover over selected earth resources ground sites.

Little need be said regarding the first factor. Obviously, some otherwise attractive mission sequences may be ruled out if the required turn-around times are unattainable.

The importance of beta stems from two distinctly separate considerations. First, there is a constraint that the workshop may not enter the z-local vertical attitude for EREP photography when beta exceeds 50°. Consequently, placing the high beta period near the center of the mission will impact EREP coverage as will be discussed in the next paragraph. Secondly, at the termination of each mission the CSM guidance platform must be aligned before separation. However, the necessary platform alignment cannot be accomplished if the orbit is totally sunlit (a minimum of about 15 minutes of darkness during an orbit is required). Consequently, the choice of SL-1 launch time and mission sequence must be such as to restrict beta not to exceed 65° (the value giving 15 minutes of night per orbit at 235 nm altitude) at the termination of each mission. Similarly, there must be sufficient darkness in the orbit to allow for a platform alignment after orbital insertion of the Skylab CSM's at the beginning of each manned mission. Somewhat higher values of beta can be tolerated since the CSM is in a lower orbit; the exact limiting value depends on the time of CSM launch.

The values of beta during the mission as a function of launch date and time can be determined from a curve presented in Reference 1.

The distribution of EREP photography opportunities, and the distributions of cloud cover over earth resources ground sites (these are, as yet, unidentified) are additional, interrelated factors to be considered. In terms of these factors the overall mission profile ideally should be designed to achieve several general objectives. First, photography opportunities should be arranged to occur near the middle of each mission, rather than at either end, in order to maximize their potential usefulness. Second, the occurrence of photography opportunities should be arranged so as to be neither too heavily nor too sparsely concentrated in any one mission. Thirdly, the occurrence of photography opportunities should be arranged to minimize disruption to the crew timeline. Interruption of a scheduled sleep period to perform an EREP pass, for example, should be avoided. And, fourth, photography opportunities of EREP ground sites should be arranged to occur at local times of day and during months of the year which assure a high probability of encountering acceptable cloud cover.

In summary, the device presented here provides an easy way to determine launch and recovery lighting conditions for a particular launch date and time. There are, however, a number of other factors which should be considered in the selection of the "best" launch times.

D. A. Corey

E. W. Radany

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Attachments

BELLCOMM, INC.

REFERENCE

1. "Preliminary Skylab Mission Planning: Graphical Determination of Lighting Considerations", Bellcomm Memorandum for File, E. W. Radany, March 31, 1970.
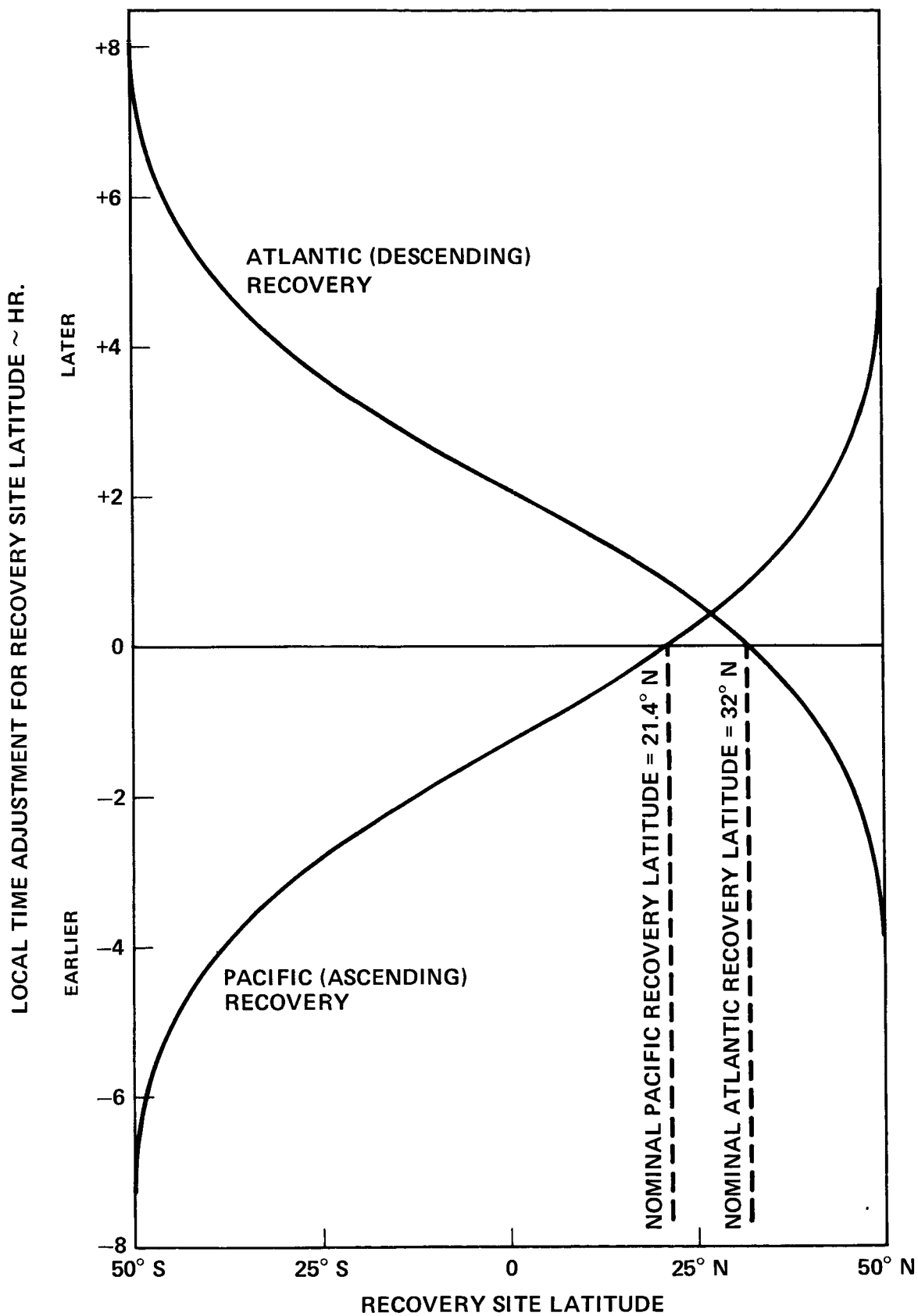
FIGURE 4 - LOCAL TIME DIFFERENCES VS RECOVERY SITE LATITUDE

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